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MINIMUM AIRDROP ALTITUDES USING STANDARD PARACHUTE EQUIPMENT

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AIR DELIVERY EQUIPMENT DIVISION

U. S. ARMY NATICK LABORATORIES
NATICK, MASSACHUSETTS

MINIMUM AIRDROP ALTITUDES FOR MASS PARACHUTE DELIVERY OF PERSONNEL AND MATERIEL USING EXISTING STANDARD PARACHUTE EQUIPMENT

ADED Report 64-2

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SUMMARY

Requirements of the Air Force Computed Air Release Point System (CARP), parachute ballistic data input to the "CARP" solution, airdrop capability of troop carrier aircraft, present and recommended airdrop altitudes, performance capability of existing standard parachute equipment and changes to existing standard parachute equipment having potential for improving its capability for use at lower airdrop altitudes, were reviewed. Minimum airdrop altitudes considered feasible using existing unmodified standard parachute equipment were determined.

BACKGROUND

a. Present airborne assault operations, carried out by Air Force troop carrier aircraft and using parachute airdrop techniques, are generally accomplished in the altitude range of 1,000 to 1,500 feet above the terrain. Requirement has been established to lower the airdrop altitude to 500 feet or below (minimum feasible) in order to minimize detection of the aircraft, reduce the enemy's air defense capability, retain the element of surprise, permit more accurate delivery and significantly improve the overall troop carrier aircraft airdrop capability.

b. Development and test is underway by the Army and Air Force of various systems which appear to have potential to provide the required lower altitude airdrop capability. However, pending adoption of any of the new developmental systems and its introduction into troop carrier aircraft operations, question has been raised as to the lowest possible altitude for mass parachute delivery of troops and materiel using existing standard parachute equipment. Purpose of this report is to define and examine the more important factors involved in making such a determination.

INTRODUCTION

It is assumed that since mass parachute delivery of troops and materiel is normally considered to encompass only those airborne operations conducted with Air Force troop carrier aircraft, there is no interest in the problems associated with operations of the type supported by Army aircraft. It is further assumed that the interest is in connection with certain combat operational requirements, rather than training. The more important factors requiring examination in connection with the subject matter, may be summarized as follows:

a. Requirements of the Air Force Computed Air Release Point (CARP) System currently used for determining the Air Release Point for airdrop from troop carrier aircraft.

b. Adequacy of data input, particularly parachute ballistic data, taken into consideration in solving and computing the Air Release Point in the "CARP" system.

c. Airdrop capability of troop carrier aircraft.

d. Present airdrop altitudes and airspeeds and Air Force (TAC) recommended changes to airdrop altitudes.

e. Performance capability of existing standard parachute equipment.

f. Changes to existing standard parachute equipment, having potential for improving its capability for use at lower airdrop altitudes.

Computed Air Release Point System (CARP)

a. The Computed Air Release Point system of air delivery was developed, tested and adopted by the Air Force in 1953. This system, commonly referred to

as "CARP" is a more scientific approach to the parachute "bonbing" problem than had previously been used. It is mechanical in nature, involving certain fundamental dead reckoning precepts and known parachute ballistics. The aircraft commander is basically responsible for the solution of the Computed Air Release Point, however, as in any bombing problem, this responsibility must be delegated to the aircrew member who is specifically trained to solve the problem. In troop carrier aircraft, that crew member is logically the navigator as "CARP" is simply another exacting navigational problem. Therefore, the navigator computes the Air Release Point and directs the aircraft to that point.

b. Air Force commanders are required to insure that the "CARP" system is used during parachute delivery operations. The only exception is when supporting Army Special Warfare Center and Special Forces. When this option is exercised by the Army, the Army release point system will be used, with the Army assuming responsibility for drop accuracy.

c. "CARP" is concerned primarily with the Impact Point of the first parachute supported object. The actual ground pattern of the remaining airdropped personnel and/or equipment is dependent upon:

(1) Time lapse between the initial signal to jump or eject cargo to the last time of exit.

(2) Formation integrity from the Target Approach Point to the Computed Air Release Point and throughout the jump or ejection periods.

(3) Uniformity of loads and/or parachute types within elements of the airdrop formation.

d. The effectiveness of the results obtained from the Computed Air Release Point system is in direct proportion to the degree of accuracy of charted data, inflight computations and crew proficiency in maintaining constant heading, altitude and airspeed.

e. Parachute Ballistics Involved in the Computed Air Release Point System (CARP).

(1) An important fundamental factor in the "CARP" solution is the parachute ballistics. The parachute ballistics taken into consideration in solving and computing the Air Release Point are:

(a) The opening time of the parachute (referred to as Opening Delay Time).

(b) The distance the parachute and load fall during the Opening Delay Time (referred to as Vertical Distance).

(c) The rate of fall of each particular parachute, after it is completely deployed and all forward motion stopped, as governed by the

weight of the parachute and load (referred to as the Standard Rate of Fall, which is subsequently corrected for air density).

(2) The ballistics of the parachutes employed in personnel, bundle and heavy equipment airdrops are many and varied. Each parachute has been designed for a specific purpose and has its own peculiar characteristics pertaining to method of deployment, opening delay time, vertical distance of fall before being fully opened and rate of descent. The ballistics of the troop type personnel parachutes are well defined as they are static line (fixed length) deployed and open rapidly. However, the behavior of the cargo parachutes is more inconsistent, due primarily to the various types of deployment methods used and their generally slower opening characteristics.

(3) One important ballistic of parachutes not considered in "CARP" and one which cannot be taken into consideration is the gliding characteristics of each parachute. As with any airfoil, parachutes have an angle of attack peculiar to their design, i.e., type parachute. This angle of attack is commonly referred to as gliding angle. The gliding angle of any given parachute can be mathematically computed and verified by wind tunnel tests, but since it is capable of gliding in any direction, its direction of glide cannot be predicted nor controlled, therefore, it is ignored. In actuality, a parachute glides in many different directions during its descent and these different glides tend to cancel each other out. If this were not the case it would be extremely difficult, at present drop altitudes, to meet the 150 yard average circular error required for personnel drops, even if other variables (such as wind effect and aircraft positioning) were negligible. The gliding effect of parachutes is what makes them appear to drift under no wind conditions.

(4) The figures included in the solution of the "CARP" system for opening delay time and vertical distance of fall before full opening are average figures which have been compiled over a considerable period of time through testing facilities and have, at least until recently, been considered accurate enough, within safe limitations, to warrant their use on all airdrops.

(5) Unsatisfactory results on airdrop operations conducted in connection with recent airborne training exercises (Swift Strike III in particular) have indicated to the Air Force (Tactical Air Command) that the parachute ballistic data currently being employed in "CARP" solutions are incorrect and in need of immediate revision. This data is contained in Eighteenth Air Force Manual No. 55-4 "Operations Computed Air Release Point Manual" and other troop carrier operational handbooks. As a result, the Parachute Branch, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio has recently been requested to TAC to provide updated data to correct this deficiency. It has further been requested that actual airdrop data be used to effect this updating.

(6) A review of the data in the Air Force Manual No. 55-4 has been made by Natick Laboratories and the results confirm the incorrectness, particularly as regards opening delay time and vertical distance of fall before full opening. Need for revision of, and addition to, rate of descent

curves is also indicated.

(7) Inadequacy of the parachute ballistic data presently being employed in "CARP" solutions is due, at least in part, to the following:

(a) Use of inadequate data acquisition equipment and methods.

(b) Failure to recognize that data obtained from test facilities such as the U. S. Army Airborne, Electronics and Special Warfare Board; U. S. Army Yuma Proving Ground and the Air Force 6511th Test Group (Parachute) has to be scrutinized carefully before use in standard load airdrop operations, to determine whether or not non-standard loads, rigging procedures, deployment methods, airdrop procedures or other special test conditions may have affected the data in such a manner as to make it unsuitable for application to standard load airdrops.

(c) Failure to revise and update parachute ballistic data, as parachute design characteristics were changed and new airdrop procedures and methods were introduced.

Airdrop Capability of Troop Carrier Aircraft

a. Throughout troop carrier airdrop history, there have been inherent limitations to accurate enroute navigation, drop zone alignment and drop accuracy, which have restricted operations to VFR conditions. Factors which limit capability are inadequate navigation equipment, inadequate drop zone aids, inaccurate maps, lack of timely photo reconnaissance support, poor communications equipment, the unpredictable effects of parachute ballistics, the inability to accurately determine drop zone winds and cumbersome, inflexible tactics. Moreover, suitable drop scoring equipment has not been available to measure results for improved training. Consequently, troop carrier procedures and circular errors of probability have not improved significantly since World War II.

b. During recent large scale airborne exercises, poor results due to inability of troop carrier units to cope adequately with marginal weather made it apparent that immediate positive action to improve troop carrier capability was essential. Accordingly the Tactical Air Command initiated a concerted effort to correct major troop carrier deficiencies.

c. First step in this direction was Phase I of TAC Programming Plan 202-62. Phase I known as Project Close Look involved a comprehensive review of the tactics, techniques, and the problems connected with troop carrier/airborne operations. Project evaluations and testing included aircraft self contained navigation and drop aids, external aids, photo reconnaissance support, and the operating procedures of aircrews, combat control teams and air weather service Pibal teams. In summary the objectives of Phase I were to obtain immediately available "off the shelf" equipment, including ground aids, and to develop new tactics in an effort to improve

the present troop carrier VFR capability and to develop an IFR capability if possible. Subsequent phases (Phase II) were to integrate useful results of Phase I into overall troop carrier/airborne operations and (Phase III) to establish long range requirements for greatly refined equipment and methods to achieve a self contained IFR airdrop capability in troop carrier aircraft.

d. Results of Project Close Look which have a particular bearing on any proposed use of lower airdrop altitudes with standard existing parachute equipment, are as follows:

(1) Testing indicated many errors in the input data to the "CARP" solution. Specifically errors were discovered in time of fall, opening delay time and the navigator's wind, taken at drop altitude many miles from the drop zone. Corrected data were recommended for updating present input data.

(2) It was determined that drop altitudes currently prescribed are excessively high, allowing large errors during time of fall. It was concluded that airdrop altitudes should be determined by the opening characteristics of the parachute being used, with release being made at the minimum safe altitude. New lower personnel and equipment airdrop altitudes were recommended.

(3) Phototheodolite data indicated that aircraft airdrop altitude errors of $\pm$ 100 feet may be encountered with present aircraft equipment. This conforms generally with other Air Force information that aircraft equipped with radar type altimeters can normally be expected to maintain their assigned airdrop altitude with $\pm$ 50 feet and that under more adverse conditions $\pm$ 100 feet is achievable. In this connection it is to be noted that when flying at 750 feet above the ground, the altimeter presently utilized in C-130B aircraft will have an error of $\pm$ 5 percent. Finding was made that once a reliable instrument for measuring absolute altitude is installed in troop carrier aircraft, altitude errors will be further reduced. While not brought out in Project Close Look, available information indicates that altitude errors as much as $\pm$ 200 feet may occur with airdrop aircraft not equipped with radar type altimeters.

(4) The tactics found to best satisfy troop arrier needs are high speed low-level navigation, in-trail formation, pop-up to drop altitude, and lower airdrop altitudes.

(5) The mixing of cargo parachutes, in an aircraft or formation, with widely varied opening characteristics not only was found to cause a large ground dispersion pattern, but also affects airdrop altitude because of the resulting spread in opening altitude. Recommendations were made that use of like type parachutes in an aircraft or formation and maximum use of quick opening parachutes, is needed to reduce ground dispersion and reduce airdrop altitude.

(6) Maximum use of G-12 type cargo parachutes on heavy equipment loads, to provide the lowest possible airdrop altitude was found

to be indicated and was so recommended. This finding was based upon the quicker opening characteristics of the G-12 cargo parachute, as compared to the slower opening, larger diameter, G-11 cargo parachute, most commonly used on heavy equipment airdrops.

Present Airdrop Altitudes and Airspeeds

a. Present airdrop altitudes and airspeeds for mass parachute delivery of troops and equipment, as specified in various Air Force manuals covering troop carrier operational procedures, may be summarized as follows:

(1) Drop altitudes for personnel

(a)	Personnel on tactical training drops	1000 feet
(b)	Personnel on wartime training drops	900 feet
(c)	Basic airborne student drops	1250 feet

(2) Drop altitudes for equipment

(a)	Equipment drops using single cargo type parachute	1250 feet
(b)	Equipment drops using G-11 and G-12 cargo parachute	1500 feet
(c)	Combination of (a) and (b) above or combination of personnel and equipment	1500 feet

(3) Drop airspeeds

(a)	Personnel and door bundles	125 knots
(b)	Equipment	130 knots
(c)	Combination (Tail Gate)	130 knots
(d)	Single aircraft with novice paratrooper personnel	115 knots

b. Special Joint Training Operations have been developed to provide for the air movement of small numbers of personnel, or small amounts of cargo, to and from isolated locations. The successful completion of these missions demand as a basic consideration: low detectability of aircraft, security of the objective area, exact timing, precise execution, and full coordination. The delivery may be made by either airdrop or landing operation. It is conducted by single aircraft flying separate routes, taking advantage of as many types of passive defense as possible. Airdrop altitudes and airspeeds

for these operations are as follows:

(1) Drop altitudes

(a)	Personnel	1250 feet maximum, 800 feet minimum
(b)	Equipment	1500 feet maximum, 500 feet minimum
(c)	Combination (Tail Gate)	1500 feet maximum, 800 feet minimum

(2) Drop airspeeds

(a)	Personnel and door bundles	125 knots
(b)	Equipment	130 knots
(c)	Combination (Tail Gate)	130 knots

c. Drop altitudes for personnel and equipment during wartime operations.

During wartime training and operations, the troop carrier commander, in conjunction with the airborne commander, will determine minimum altitudes for personnel and equipment drops. This flexibility undoubtedly is required to permit field commanders to meet the various operational requirements they will be confronted with. However, there appears to be a serious lack of published data to guide them in making such a determination.

d. Drop altitude for aircraft emergency bailout of paratroopers.

When an aircraft emergency occurs, during the time or after the paratroopers stand up and hook up, the emergency bailout procedure is as follows:

Maintain an acceptable altitude and attitude for the paratroopers to evacuate the aircraft. The minimum acceptable altitude is 400 feet above the terrain. If the jump must be made at an airspeed in excess of 150 knots indicated airspeed, paratroops will be advised of the airspeed and altitude. In this case the paratroopers will normally not use the static line but instead employ their reserve parachute in a jump and pull manner.

Airdrop Altitudes Recommended in Air Force (TAC) Project Close Look

In Air Force (TAC) Project Close Look it was determined that drop altitudes currently prescribed are excessively high, allowing large errors

during time of fall. As a result the following new airdrop altitudes were proposed:

a.	Personnel drops using the T-10 Personnel parachute	1000 feet
b.	Equipment drops using the G-12C cargo parachute. It should be noted that the Army, for logistic purposes, is currently converting all stocks of G-12C cargo parachutes to the G-12D design. In addition procurement data is being changed so that all future procurements will be of the G-12D design.	500 feet
c.	Equipment drops using the G-12D cargo parachute	600 feet
d.	Equipment drops using the G-11A cargo parachute	1000 feet

<u>Performance Capability of Existing Standard Parachute Equipment</u>

a. Personnel Parachutes

(1) The T-10 troop back personnel parachute, (A/P28S-2) currently standard for use in the conduct of most troop type low altitude (1,000 - 1,500 feet above the terrain) airdrop operations from Air Force and Army aircraft, is a static line deployed parachute which exhibits good positive opening characteristics, as evidenced by the fact that it readily passes the twisted lines test of Air Force Specification Bulletin No. 505 covering "Parachutes, Personnel, Testing Standards for." This test, intended to determine opening characteristics of a parachute, is conducted with a 250 pound drop test dummy from an airdrop altitude of 500 feet above the terrain and at an indicated airspeed of 110 knots. The canopy is packed with three complete 360 degree twists applied to the suspension lines in a location (not to exceed 30 inches) just below the skirt. A successful test requires the canopy to be fully inflated and in equilibrium prior to contact of the dummy with the ground. Forty consecutive tests without failure are required for a canopy design to pass this standard. This parachute is the one employed for mass parachute delivery from troop carrier aircraft and has been proven in troop use to be highly reliable and safe.

(2) The other static line deployed troop back personnel parachute (A/P28S-11) standard for use in the conduct of troop type low altitude (1,000 - 2,000 feet above the terrain) airdrop operations from Air Force and Army aircraft, is equipped with a modified T-10 parachute canopy incorporating a single orifice and slip risers to provide improved maneuverability and steerability over that attainable with the conventional T-10 canopy. This parachute also passes the twisted lines test and has been successfully dummy drop tested and live jump tested to altitudes as low as 500 feet above the terrain. Because of the possibility of mid-air jumper

collisions when using the maneuverable and steerable features of this parachute, its use has been restricted to single aircraft or single aircraft in trail formation. Its use in mass jumps from aircraft in formation, other than single aircraft in trail, is not recommended. This parachute is intended for use primarily by Special Forces personnel and may be used in making water jumps with Self Contained Underwater Breathing Apparatus (SCUBA) gear. Normal Special Forces use involves single aircraft, special operations type, missions where a maximum of approximately 30 jumpers will be airdropped.

(3) Although the maneuverable troop back personnel parachute canopy is a modified T-10 design, test data indicates that these modifications have not altered the performance characteristics of the basic T-10 canopy.

(4) The ballistics of the above discussed troop type personnel parachutes are well defined, as they are deployed by a static line of fixed length and open rapidly and reliably. Further, valid data from both dummy and live jump airdrop tests, performed under operational conditions, are available upon which to assess performance capability. More recently, additional data became available as a result of instrumented coverage of 184 T-10 personnel airdrops made in connection with Project Close Look. Results of these tests (Project Close Look) indicate the following:

(a) The opening delay time for the T-10 parachute (2.6 seconds at 125-130 knots) currently used in "CARP" for plotting opening delay distance, is correct. It should be noted that opening delay time figures used in "CARP" represent one-half parachute opening time plus one second reaction or exit time. Based upon this "CARP" definition, it becomes apparent that the 2.6 seconds opening delay time is in accordance with the generally accepted opening time for the T-10 parachute of 3.2 seconds at 130 knots.

(b) The personnel airdrop altitude can be reduced from 1,250 feet to 1,000 feet, which was found safe and feasible.

(c) On the personnel airdrops, phototheodolite data on both the actual airdrop altitude (exit altitude and the deployment altitude, (parachute opening altitude)) were obtained. This data indicates that when making similar drops, with the equipment used during the project, (C-130 aircraft, nominal airdropaltitude of 1,000 feet above the terrain, 125 knots drop airspeed, T-10 parachute) it can be expected 95 percent of the time that the deployment altitude (parachute opening altitude) will be within the range of 663 - 965 feet above the terrain. For deployment altitude (184 drops), mean was 814 feet, median 817 feet, mode 838 feet and standard deviation 77 feet.

(5) At the present airdrop altitudes, certain of the more common personnel parachute deployment malfunctions, such as twisted lines and semi-inversions, may be successfully corrected by a jumper during descent, thus obviating the necessity for activating his reserve parachute. At lower airdrop altitudes, the jumper will have little opportunity to attempt such corrections and will instead have to make an immediate decision as to

whether or not he should activate his reserve parachute.

(6) At lower airdrop altitudes, acceptance must be made of the fact that the reserve parachute will be less effective and will not provide the emergency rescue capability it does at present airdrop altitudes. This is based upon the following:

(a) There will be less time for the jumper to recognize the existance of a main parachute malfunction and react by activating his reserve parachute.

(b) The present design of reserve parachute does not always deploy and open properly under either complete or partial main parachute malfunction conditions. As a result the jumper may take certain actions to assist the reserve in deploying and opening. Less time will be available for these actions before the jumper will have to desist and assume a landing attitude.

(7) Normally in mass parachute delivery of troops it may be expected that some jumpers will be jumping with heavy weapons and individual equipment containers attached to their parachute harness. These containers are designed to accommodate designated combat equipment and may weigh as much as 120 pounds when loaded. An 18 foot lowering line, attached on one end to the parachute harness and on the other end to the container, provides a means of removing the container from the jumpers body prior to landing and thus reduces possibility of injury on landing. Normally the container is dropped onto the lowering line at approximately 200 feet above the ground. Experience has shown that with some jumpers such a heavily loaded container presents a sort of a "mental block" in that they become so absorbed in the problems of exiting with it and handling it in the air and during landing, that they ignore all other considerations, such as accomplishment of the five points of individual performance essential in parachute jumps, and fail to quickly recognize and react to in-the-air emergencies requiring use of the reserve parachute. Use of lower personnel airdrop altitudes may be expected to increase this problem and also provide less time for the jumper to carry out specified procedures for safely lowering his container without endangering other jumpers around him.

(8) An increase in the landing injury rate may be expected to accrue as a result of the limiting factors discussed above.

b. Cargo Parachutes

(1) Much of the performance data presently available on standard cargo parachutes, used in the conduct of airdrop operations, were developed in connection with test programs involving developmental airdrop equipment and therefore must be used with caution because of the possible influence of non-standard loads, rigging methods and airdrop procedures. Most recent data, acquired under more or less standard airdrop conditions, are those established in connection with the Air Force (TAC) Project Close Look

(15 September 1962 - 22 March 1963). This project, conducted by the Tactical Air Command, was provided air delivery support by the 101st Airborne Division and the Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio provided data acquisition, reduction, and analysis support.

(2) Results from Project Close Look which are pertinent to presently used cargo parachutes are as follows:

(a) The opening delay times for G-12C, G-12D and G-11A cargo parachutes, currently used in "CARP" for plotting opening delay distance, are incorrect. Correct values found and recommended for future use are as follows:

G-12C cargo parachute - 6.8 seconds instead of the present 3.5 seconds

G-12D cargo parachute - 7.8 seconds instead of the present 5.0 seconds

G-11A cargo parachute - 5.3 seconds instead of the present 6.5 seconds

(b) Analysis of the changes found necessary in opening delay times indicates that the errors in opening delay times involved that part of the opening delay time pertaining to exit time for the load. Accordingly the corrected opening delay times now include more correct exit times. That part of the opening delay times pertaining to parachute deceleration or opening time was found to be correct. Opening times for the parachutes concerned are as follows:

1. G-12C cargo parachute - 5.0 seconds

2. G-12D cargo parachute - 8.0 seconds

3. G-11A cargo parachute - 11.0 seconds

(c) The above times represent average values based upon an airdrop speed of 130 knots and while those for the G-12D and G-11A cargo parachutes may be slightly high they are considered adequate for use in the "CARP" solutions.

(d) Although data were recorded on both airdrop (load exit altitude) and deployment (parachute opening) altitude for personnel airdrops made in connection with Project Close Look, only airdrop (load exit) altitude was determined on equipment airdrops. Accordingly, information on vertical distance from load exit to parachute opening was not obtained. This was unfortunate, as review of the vertical distance table used in the "CARP" solution indicates some of the values for cargo parachutes are inaccurate. Generally they are too low.

(e) Drop altitudes currently prescribed for A-22 containers and heavy equipment platforms were found to be excessively high, allowing large errors during time of fall. An airdrop altitude of 600 feet for A-22 containers using the G-12D cargo parachute and 1,000 feet for heavy equipment platform type loads using the G-11A cargo parachute was found adequate.

(f) Mixing of different types of cargo parachutes, with varying opening characteristics, in the same aircraft or formation was found not only to result in large ground dispersion of loads but also to be a limiting factor in lowering airdrop altitude. Coordination was recommended between the Air Force and Army during rigging and loading operations to insure use of like type parachutes in an aircraft or formation and maximum use of quick opening parachutes for minimum drop altitude.

(g) Conclusion was reached that airdrop altitudes should be determined by the opening characteristics of the parachutes being used, with release being effected at the minimum safe altitude.

(3) As a result of recent difficulties experienced in quickly packing relatively large numbers of various types of cargo parachutes for a possible operational use, decision was made that a certain number of cargo parachutes must be maintained in a packed condition for contingency purposes. Present repack interval for cargo parachutes is one year in temperate climate and six months in the arctic. In order to minimize the continuing repack workload which would be involved in meeting the contingency requirement, while adhering to present repack interval requirements, a test program has been developed to acquire engineering data upon which to base a decision as to what the maximum repack interval is that can be safely used with these parachutes. Goal is a repack interval in the 3 - 5 year range. It may be found that, in order to achieve an acceptable repack interval, acceptance will have to be made of some increase in parachute opening times which may accrue as a result of these parachutes being maintained in a packed condition for a long interval. In this connection, it must also be recognized that after approximately 3 years from date of manufacture, presently used 2 second delay reefing line cutters for accomplishing disreefing of the G-11A cargo parachute to permit it to fill to a full open configuration, may be expected to provide longer delays (increases of up to 2 seconds are indicated) than normal, thus increasing opening times. Any increase in parachute opening times is of course undesirable at low airdrop altitudes.

(4) Action is currently underway in the Army to convert all stocks of G-12C cargo parachutes to the G-12D design. Procurement data is also being changed to reflect the G-12D design. While this action was initiated for logistic purposes, it will also improve airdrop operations since while both configurations were in field use, different packing procedures had to be observed and their different opening characteristics had to be taken into account in "CARP" solutions.

(5) Use of break-a-way type static lines for cargo parachutes to "clean up" the aircraft after drop, while proving effective for their

intended purpose, generally do not provide as positive, consistent and reliable parachute openings.

(6) An important factor to be considered in heavy equipment (platform type loads) airdrops is load oscillation. Airdrop altitude must be sufficient to permit damping of load oscillations prior to ground impact, otherwise the incidence of load damage from overturn may be expected to increase.

(7) In connection with heavy equipment (platform type loads) consideration must be given to the effect of lowering airdrop altitude on the proper operation of the parachute release/releases used with such loads to separate the parachutes from the load upon contact of the load with the ground. Present parachute releases employ a 10 second delay in the arming of the release so as to prevent mid-air release of parachutes due to a no-load condition which may occur during parachute deployment and opening. Initiation of this time delay occurs at initiation of parachute deployment. A new 5,000 Pound Capacity Cargo Parachute Release, intended to replace the currently used Single Release Assembly and Multiple Release Assembly (Finger Type), is currently in production and will soon be in field use. The new release utilizes a 20 second time delay and therefore presents a limiting factor, as regards minimum airdrop altitude, since total down time for the load must be sufficient to permit arming of the release before ground impact of the load. Otherwise the release may not become armed until after load impact, thus presenting the possibility of the load being dragged or overturned and damage incurred. Under such a condition the design intent of the parachute release would be negated as it should be armed prior to load ground impact. Development is underway for a variable 10-20-30 second delay for use with this new parachute release.

<u>Changes to Existing Standard Parachute Equipment Having Potential for Improving its Capability for Use at Lower Airdrop Altitudes</u>

a. Personnel Parachutes

(1) A current development in the personnel parachute area, which is of interest in connection with the achievement of improved reserve parachute performance at lower airdrop altitudes, is that pertaining to a ballistically deployed reserve parachute. This parachute which employs a ballistic system to deploy the canopy and suspension lines (standard 24-foot diameter flat curcular reserve parachute canopy) to a fully elongated condition is intended to eliminate the entanglement problem between main and reserve parachute canopies, as well as provide a quicker, more positive opening, reserve parachute. Engineering tests are in the final stages and results indicate success in achieving the desired improved performance, as no instances of reserve and main parachute canopy entanglement have occurred and reserve opening has been achieved in the full range of simulated main parachute malfunctions, from streamer to full open canopy with a line-over.

(2) In view of the success with the internal parachute canopy concept in reducing Air Force types C-9 and C-11 personnel parachute canopy

opening times and decreasing the spread of opening times, consideration to investigate the potential of this concept with the T-10 canopy is believed to be warranted. Not only may an improvement in canopy opening characteristics be achieved, but also an improvement in semi-inversion rate attained.

b. Cargo Parachutes

(1) An investigation of the internal canopy concept, presently being carried out jointly by the Army and Air Force, appears to have potential for lowering the airdrop altitude capabilities of the G-12 and G-11 cargo parachutes which singly and in clusters are currently used with A-22 and equipment (platform type) airdrop loads.

(a) This investigation in its present scope is concerned with the application of the internal parachute canopy concept to the G-11A cargo parachute for both single canopy and cluster loads, with the intent of reducing opening time with only a slight increase in opening force.

(b) This concept, which evolved from the joint services sponsored University of Minnesota program covering investigations in the field of aerodynamic decelerators, involves the use of a small diameter (13-16 foot) flat curcular internal parachute canopy located just inside the main parachute canopy (approximately 3.5 feet above the canopy skirt).

(c) The concept was conceived to increase the rate of change of the main canopy inlet area during the initial part of the filling process which would result in a decrease of the total filling time with only a slight increase in opening force.

(d) Airdrop test data from tests of personnel parachutes (Air Force C-9 and C-11 types) rigged with internal parachutes have confirmed wind tunnel data and have shown that an internal parachute of the correct size and properly positioned is capable of modifying the main parachute canopy opening characteristics by reducing opening times and decreasing the spread of opening times achievable with a particular design of parachute. Rigging of the internal canopy is quite simple, involving no actual modification of the main parachute canopy and presenting no complications to packing.

(e) Airdrop test data from single G-11A canopy (with internal parachute) load tests, verify that achievement of a reduction in parachute opening time and altitude loss (from load exit to parachute opening) is possible. Further, the use of an internal parachute appears to produce a reduction in the spread of opening time and altitude loss, an important factor in any consideration being given to lowering airdrop altitude. Achievement of a minimum airdrop altitude of 600 feet with a single G-11A canopy load is indicated to be feasible. Airdrop tests of cluster G-11A cargo parachutes equipped with internal canopies are currently being programmed.

(2) Drop altitude for single canopy G-11A cargo parachute

loads can be reduced by not reefing the canopy for these loads. An average reduction in opening time of 2.8 seconds appears attainable, based upon limited airdrop test data. However, when used in clusters for heavier loads the G-11A cargo parachute must be reefed in order to achieve consistent and reliable opening characteristics and prevent canopy damage. Accordingly, requirement would be presented to maintain G-11A cargo parachutes in two different packed configurations, reefed and unreefed. This would present an unacceptable logistic burden, not only on field units but on the program for maintaining a certain quantity of cargo parachutes packed at all times for contingency purposes. Almost certainly a problem would also be presented as regards the possibility of unreefed parachutes being used in cluster parachute drops.

(3) The G-12 cargo parachute was originally introduced into Army use as the recovery parachute for A-22 container loads. Subsequently, with the adoption of the now standard G-12D configuration, which utilizes a deployment bag rather than the former envelope type pack, this parachute came into use in clusters of up to three for recovery of equipment loads.

(a) This parachute (64 foot diameter flat circular canopy) possesses quicker opening characteristics than the G-11A cargo parachute (100 foot diameter flat circular canopy) which is the one most extensively used on equipment loads. Addition of a reefing system to the G-12D canopy (unreefed canopies in clusters of more than three sustain unacceptable damage) would permit its use in larger clusters and would be a feasible approach to lowering the airdrop altitude for at least part of the equipment loads.

(b) During tests of an early dual rail air delivery system concept, a skirt reefing system was added to the G-12D parachute and larger cluster tests conducted. Recommendation of the test agency that a reefing system not be added to the G-12D cargo parachute to extend its use to larger cluster drops was based upon the following:

1. For comparable loads, use of G-11A cargo parachutes was found to be more economical.

2. For comparable loads, use of G-12D cargo parachutes in lieu of G-11A cargo parachutes requires acceptance of a weight and bulk penalty.

3. Two different packed configurations of G-12D cargo parachute would have to be maintained, unreefed for A-22 container recovery and reefed for equipment loads.

(c) Changed conditions since the above recommendation was made, indicate a re-examination of the various factors involved is warranted.

Minimum Airdrop Altitudes Considered Feasible Using Existing Unmodified Standard Parachute Equipment

a. Personnel and Door Bundles

(1) Taking into consideration available airdrop data and qualifying it with the previously discussed limiting factors involving aircraft operational capability, parachute equipment and jump procedures, it is considered that a personnel airdrop altitude of 750 feet above the terrain is the minimum safe altitude at which the maximum recovery capability of the static line deployed troop type personnel parachute assemblies can be expected under mass airdrop conditions. Drop airspeed would be 125 knots minimum. This airdrop altitude also permits airdrop of accompanying A-7A sling and A-21 bag 300 to 500 pound door bundle loads using G-1A, T-10 reserve converted to cargo, T-7 main converted to cargo and G-13 cargo parachutes. Conduct of airdrop operations at this airdrop altitude should be restricted to training for imminent combat operations or the conduct of such operations.

(2) In combat operations where accomplishment of the mission is paramount and some acceptance of safety compromises must generally be made, a personnel airdrop altitude of 600 feet above the terrain appears to be feasible (except for SCUBA gear jumps with the maneuverable parachute assembly) provided: airdrop speed is closely maintained, troop carrier aircraft are equipped with a reliable instrument for measuring absolute altitude and the airdrop altitude is closely maintained, well trained and proficient aircrews are available, it is accepted that the reserve parachute will be less effective as an emergency recovery device and it is recognized that an increase in landing unjury rate may accrue. Drop airspeed would be 125 knots minimum. SCUBA gear jumps with the maneuverable parachute assembly should be conducted observing a minimum airdrop altitude of 750 feet. The 600 feet airdrop altitude also permits airdrop of accompanying A-7A sling and A-21 bag 300 to 500 pound door bundle loads using G-1A, T-10 reserve converted to cargo, T-7 main converted to cargo and G-13 cargo parachutes.

b. Door Bundles and Equipment

Based upon presently available airdrop data, and again taking into account the various previously discussed limiting factors, it is considered that the following airdrop altitudes are the minimum safe and feasible for use in door bundle and equipment airdrops. Drop airspeed would be 130 knots:

(1) Equipment

(a) A-7A sling and A-21 bag 300 to 500 pound loads for simultaneous individual delivery in quantity from aircraft ramp, using G-1A, T-10 reserve converted to cargo, T-7 main converted to cargo and G-13 cargo parachutes.	600 feet minimum

(b)	A-22 container loads with G-12D cargo parachutes.	600 feet minimum
(c)	Equipment (platform type loads) with single or clustered G-12D cargo parachutes.	800 feet minimum
(d)	Equipment (platform type loads) with single or clustered G-11A cargo parachutes.	1,000 feet minimum
(e)	Equipment (platform type <u>piggy-back</u> loads) with clustered G-12D cargo parachutes and single G-11A cargo parachute.	1,500 feet minimum

c. Combination (Tail Gate)

Combination drops are defined as those drops during which parachutists exit from the aircraft tail gate immediately after the ejection of equipment (platform type loads) or airdrop containers (A-7A sling, A-21 bag, A-22 container). Combination drops are restricted to single ship, single element, or to the last element of a heavy equipment/supply section. Drop airspeed would be 130 knots.

(1) Equipment

(a)	Airdrop containers (A-7A sling, A-21 bag, A-22 container) using G-1A, T-10 reserve converted to cargo, T-7 main converted to cargo, G-13 and G-12D cargo parachutes; followed by personnel.	750 feet minimum (training for imminent combat operations and combat operations). 600 feet minimum (combat operations where accomplishment of the mission is paramount and safety compromises are acceptable).

(2)	Equipment (platform type loads) with single or clustered G-12D cargo parachutes, followed by personnel.	800 feet minimum.
(3)	Equipment (platform type loads) with single or clustered G-11A cargo parachutes, followed by personnel.	1,000 feet minimum.

(4) Equipment (platform type piggy-back loads) with clustered G-12D cargo parachutes and single G-11A cargo parachute, followed by personnel. | 1,500 feet minimum.

(Quite recently attention was focused on the possibility that requirement may exist to airdrop personnel, supplies and equipment onto drop zones which are from 14,000 to 18,000 feet above sea level. In examining the problems associated with such a requirement certain factors became apparent which would have a bearing on any contemplated use of lower airdrop altitudes at high drop zone elevations. These factors included increase in rate of descent, increase in the time to reach equilibrium velocity and a stable condition. Natick Laboratories has submitted to the U. S. Army Materiel Command, under previous correspondence, an evaluation of the problem areas and made certain recommendations pertaining to them. The findings of this report, pertaining to the use of lower airdrop altitudes, should not be construed as applying in any way to the requirement referred to above.)